Planning for NOAA's Operational Satellites for 2030 and Beyond-Priority Objectives from the Space Platform Requirements Working Group (SPRWG)

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22nd Conference on Integrated Observing and Assimilation System for the Atmosphere, Oceans, and Land Surface (AOAS-AOLS)

Session 2: Current and Future Observing Systems

8 January 2018

Outline of Presentation

- *SPRWG Charge and Membership*
- *Summary of SPWRG Activities*
- *The Environmental Data Record (EDR) Value Model (EVM)*
- *Priority setting*
- *Sample results*

Much more background and results presented Wednesday January 10
NOAA Satellite Observing Systems Architecture Study (NSOSA)
Salon H (Hilton) 8:30-12:00

SPRWG Membership: NOAA Line Offices, NASA, Academia, and Private Sector

NOAA Line Offices, NASA, Academia, and Private Sector

1. Rick Anthes, Chair (UCAR)
2. Steve Ackerman (U Wisconsin, CIMSS)
3. Bob Atlas (NOAA, AOML)
4. Lisa Callahan (NASA GSFC)
5. Jerry Dittberner (Consultant)
6. Rich Edwing (NOAA, NOS)
7. Pam Emch (Northrop Grumman)
8. Michael Ford (NOAA, NMFS)
9. Bill Gail (Global Weather Corp)
10. Mitch Goldberg (NOAA liaison)
11. Steve Goodman (NOAA liaison)
12. Chris Kummerow (CSU)
13. Terry Onsager (NOAA, NWS, SWPC)
14. Kevin Schrab (NOAA, NWS)
15. Chris Velden (U Wisconsin, CIMSS)
16. Tom Vonderhaar (CSU)
17. Jim Yoe (NOAA, NWS, NCEP liaison)
18. Jeff Reaves (Executive Assistant

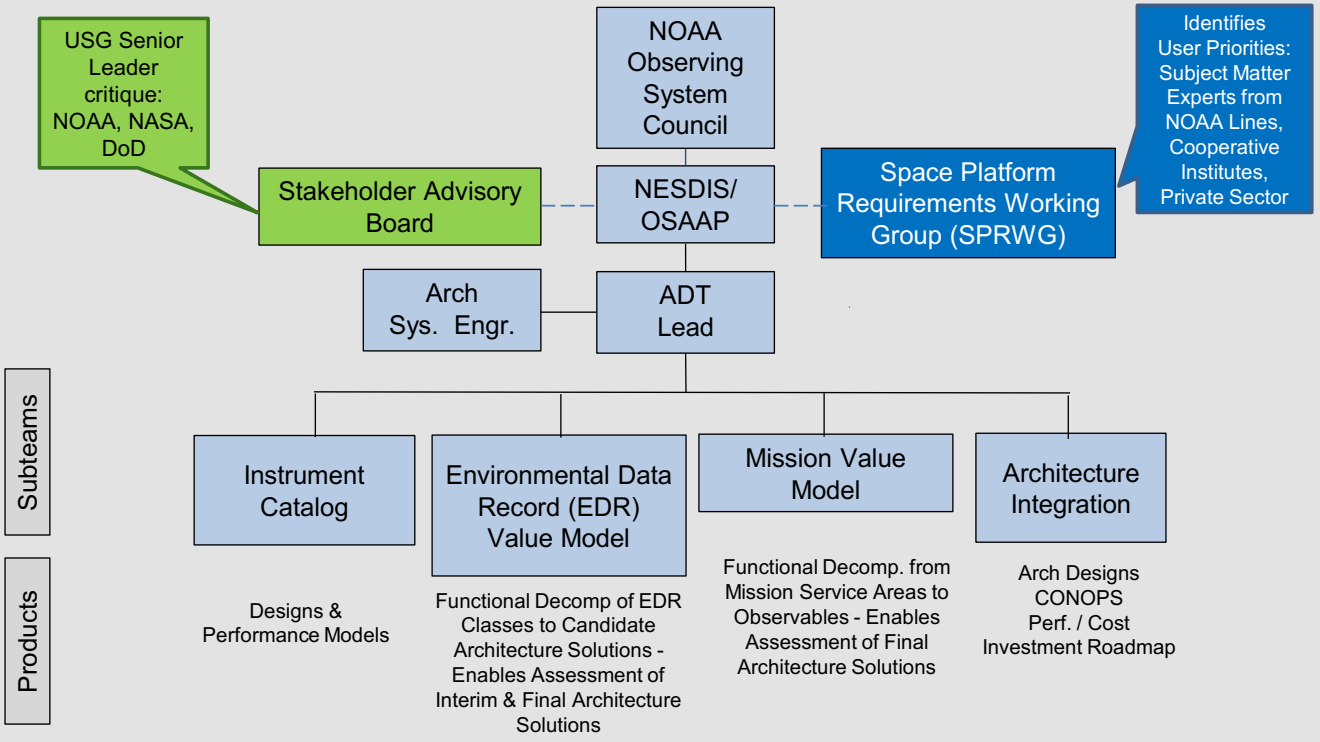
SPRWG Meeting 20 June 2017 NCAR

SPRWG Charge

- ***Determine needs and relative priorities for weather, space weather and environmental remote sensing space-based observations in the epoch of 2030 in support of the NSOSA (NOAA Satellite Observing System Architecture) study***
- ***Priorities are NOAA operational functions***
- ***SPRWG has no decision authority***
- ***SPRWG will participate in developing the Environmental Data Record (EDR) value model (EVM)***

SPRWG Role in NSOSA Study

NSOSA Study Team Structure & Products



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NSOSA

History of SPRWG Activities

- October 2015-Terms of Reference and appointment of SPRWG members
- Dec 2-3 2015-First meeting of SPRWG in Silver Spring Md.
- January 12-13 2016-Town Hall meeting at AMS Annual meeting and second meeting of SPRWG
- Feb 4-5 2016-Third meeting of SPRWG in Silver Spring Md.
- March-May 2016-Many conference calls with Group A and B leaders and Mark
- May 24 2016-SPRWG Cycle 1 Report
- July 13-14 2016 Fourth meeting of SPRWG Boulder
- October 31 2016 SPRWG Cycle 2a Report
- Jan 11-12, 2017-Fifth SPRWG meeting in Boulder
- May 15, 2017-SPRWG Final Report
- June 20-21, 2017 Sixth SPRWG meeting in Boulder

SPRWG was an “in the weeds committee”-details are very important!

The EVM (Environmental Data Record (EDR) Value Model)

- ***The EVM is a table listing each objective (sometimes called "requirements") for NOAA's space-based observational system of 2030 and beyond, together with the performance attributes of each objective.***
- ***A Functional Objective (often just Objective) is something we want to measure-e.g. temperature soundings, a visible image, a solar corona image.***
  - *Group A-Weather, climate, oceans, chemistry objectives*
  - *Group B-Space weather objectives*
- ***There are also Strategic Objectives, such as assurance of core capabilities (Group D Objectives)***
- ***There was originally a Group C (Communications Objectives), but this was not ultimately included in study.***
- ***SPRWG focused on Group A and B objectives***

Performance attributes for each Objective

- *Performance attributes are properties of an objective such as horizontal and vertical resolution, accuracy, update rate, latency.*
- *Must be specified for three levels of capability-see next slide*
- *Specification based on many references, especially WMO OSCAR and NOAA COURL documents, plus many peer-reviewed publications and judgment of experts on SPRWG*
- *One of the most time-consuming parts of the project, and involved many iterations and discussions with Architecture Development Team*

EVM Capability Levels

- ***Set capability levels for objectives to include:***
  - *Study Threshold: The level at which decreases in capability no longer present a compelling investment, i.e., alternatives with capability below this level will be rejected. Guidelines are no objectives with ST level greater than Program of Record 2025.*
  - *Expected: The capability reflecting consensus expectations from the users. Often, but not always, roughly equal to today's capability.*
  - *Maximum Effective: The level at which increases in capability no longer present a compelling investment (i.e., alternatives with capability above this level will receive no additional credit). Generally a significant improvement over today's capability.*

Example of an Objective Global real time IR soundings

- ***Performance attributes at ST, EXP and ME levels***
  - *Horizontal resolution (km)* — *15, 10, 1*
  - *Update rate (hours)* — *12, 3, 1*
  - *Latency (hours)* — *3, 1, ¼*
  - *Vertical resolution (km)* — *2, 1.5, 1*
  - *Accuracy temperature (K)* — *1, 0.75, 0.5*
  - *Accuracy specific humidity (g/kg)* — *2, 0.2, 0.15*

EVM Example: Objective A1

A	B	C	D	E	F	G	H	I	J	K
Objective number	**Objective**	**Attribute**	**Program of Record 2025**	**Comments/questions**	**Study Threshold (ST)**	**Expected (EXP)**	**Eff scale of EXP level**	**Maximum Effective (ME)**	**Overall rank order**	**Overall swing weight**
Group A: Weather and ocean objectives		**Attribute values "soft," i.e. flexible +/- 15%.**	**POR2025 defined in SPRWG Final Report**	**Final EVM 5/15/17**	**ST values required to be at or below POR 2025. If an objective is not in the POR2025, it is assigned an ST value of zero (none).**	**Level that users expect in 2030**	**Must be between 0 and 100**	**Level at which further improvement are deemed not useful**	**Rank order priority is for improvements above ST level, not absolute priority of objective.**	**Swing weights based on tanh model (see SPRWG report)**
								100		
A1	Regional real-time weather imagery	Imagery of N/S America, W. Atlantic, E. Pacific to at least 65N and westward just past the dateline with latency <10 min, and update faster than 30 minutes.	GOES-16, S, T and U	Assuming Advanced Baseline Imager (ABI) on GOES-16 and all products it supports			70		2	0.1232025
		Ground-projected instantaneous field of view (GIFOV) nadir view		GIFOV is called "horizontal resolution" in COURL. Also sometimes called Ground Sampling Distance (GSD). See SPRWG Report for details.						
		Visible	0.5 km	narrow band near 0.55-0.65 microns	2 km	0.5 km		0.25 km		
		IR	2.0 km		4 km	2 km		1 km		
		Near IR	1 km	0.86-1.6 microns	3 km	1 km		0.3 km		
		Sampling frequency (update rate)	5 min	ABI	30 minutes	5 minutes		2.5 minutes		
		Latency (image time to delivery)	1 min		10 minutes	5 minutes		2.5 minutes		
		Mesoscale (movable 1000kmx1000km)		ABI						
		Number of Regions in CONUS	2 (moveable)	ABI	1 in CONUS (fixed domain)	2 (moveable)		5 (moveable)		
		Update rate	0.5 min		7 min	30 s		15 s		
		Latency (image time to delivery)	0.5 min		7 min	30 s		15 s		
		Wavelengths covered		ABI						
		Lower edge of coverage	0.47 microns		0.630 microns	0.47 microns		0.4 microns		
		Upper edge of coverage	13.7 microns		11 microns	13.35 microns		13.7 microns		

Developing the EVM (Environmental Data Record (EDR) Value Model)

- ***SPRWG broke into two subgroups***
  - *Group A for terrestrial weather, climate, oceans and atmospheric chemistry*
  - *Group B for space weather*
  - *Each subgroup consulted outside subject matter experts as needed. This was especially important for Group B, which was underrepresented in the SPRWG.*
- ***Each Group developed a list of objectives based on known user needs and many WMO, ESA, NRC and NOAA documents. By coincidence, each group defined 19 objectives.***
- ***Each Group explicitly considered whether user needs and/or science/technology would radically change from today by 2030. Answer was "no," fundamental needs (images, NWP initial data, solar and upper atm obs) will be same.***
- ***SPRWG determined the ST, EXP and ME levels performance of each quality attribute of each Objective though personal knowledge of SPRWG subject matter experts (SME), discussions with outside SME, and with consideration of external independent references, notably WMO OSCAR and NOAA COURL.***

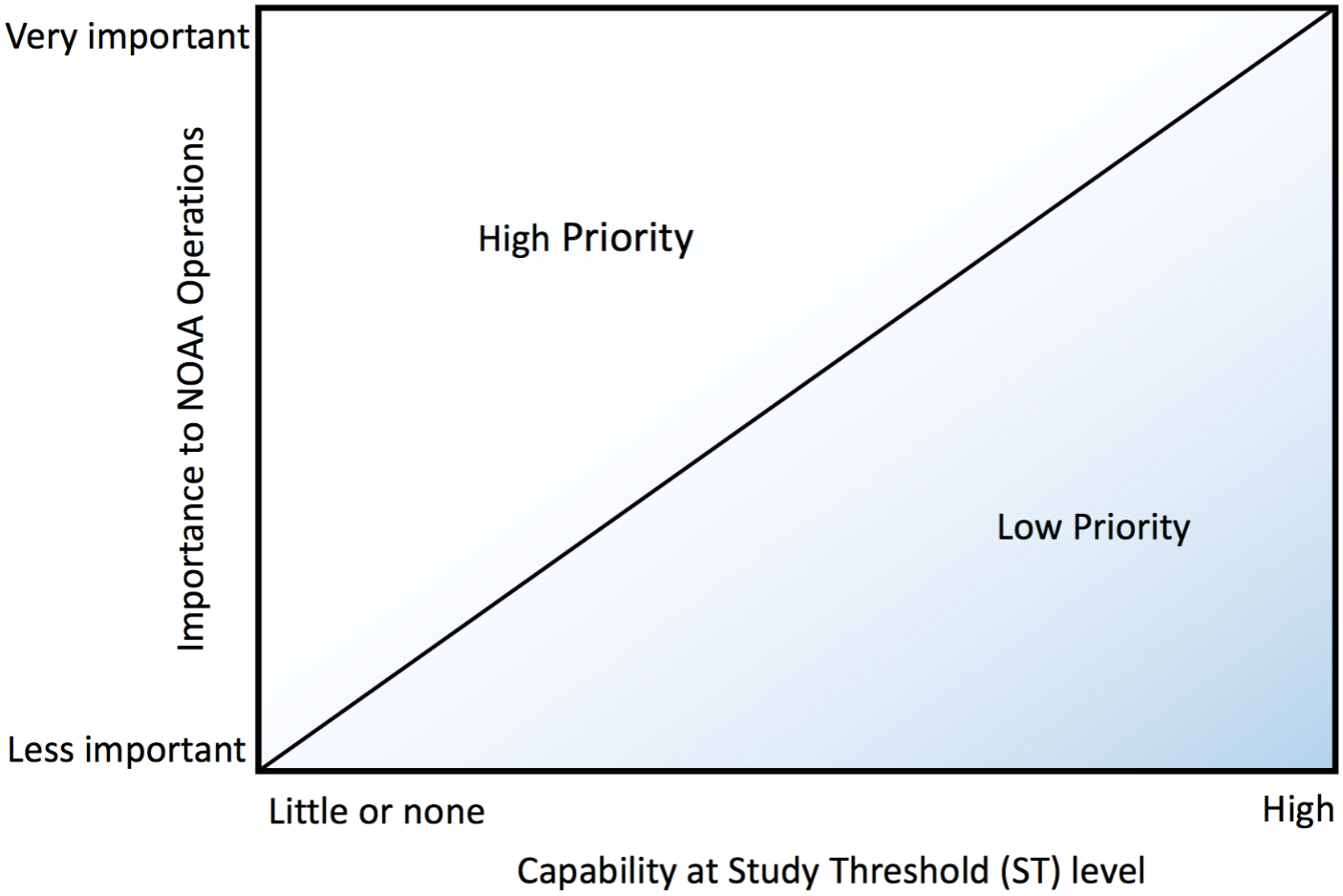
Developing the EVM, continued

- *SPRWG ranked the objectives in each Group according to their impact on the NOAA operational mission of improving the performance from the ST to the ME level. Preliminary rankings were debated extensively and changed in a number of cases based on the debate. In the end there was consensus on the ranking within Groups A and B.*
- *We did the ranking based on the general agreement that the items near the top were significantly higher priority than those near the bottom, but that the swing weights of items grouped closely together should be close in magnitude because it was difficult to distinguish, for example, between the 10th and 11th ranked objective. This led to a hyperbolic tangent form for the swing weights. Sensitivity tests of the impact of small changes in ordering on architecture designs and scoring supported this philosophy (the results were not sensitive to minor re-ordering of priorities).*
- *SPRWG wrote "two pagers" for each Objective, justifying their importance to NOAA and why they were ranked in priority the way they were. References were provided to support each objective and its relative importance for improvement in capability.*
- *SPRWG worked closely with the NSOSA Architecture Development Team throughout study*

Priorities for Objectives in EVM

- ***Priorities based on impact of improvement of objective from ST to ME level***
- ***Objectives in Groups A and B prioritized separately by SPRWG***
- ***Group D (Strategic Objectives) prioritized by NOAA management***
- ***All objectives integrated into one priority list by NOAA management (44)***
  - *Relative priorities within each Group preserved*
- ***Swing weights (numbers between 0 and 1 indicating priority in moving performance attributes of objective from ST To ME level) assigned for each objective according to a tanh model.***

Priorities-based on improvement over ST level of capability, NOT intrinsic priority to NOAA

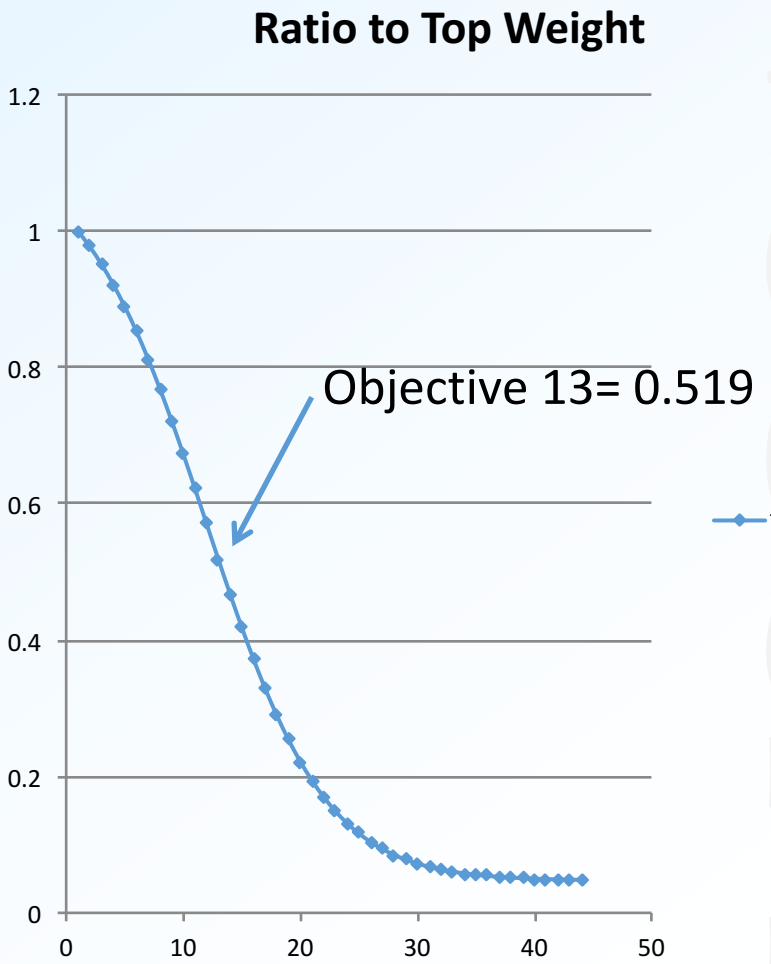


Swing Weight Model

Tanh model

$W(i) = eps + [1-\tanh((R/N)(i-mid))]^{p}$

N=44
p=1.2
eps=0.1
Range=4
mid=13



Major References

- *ESA, 2014: The Earth Observation Handbook 2015. 47 pp. [Available online at http://database.eohandbook.com]*
- *WMO, 2013c: Observing Systems Capability Analysis and Review (OSCAR) Tool. [Available online at http://www.wmo.int/oscar/] OSCAR Version 2015-12-12.*
- *NOAA Consolidated Observing User Requirements List (COURL); Version dated Dec 8, 2015. Spread sheet title: "COURL Request 12-08-15_loc.xls" . Most of the space weather objectives used an updated and revised version titled "SWX CORL_SWX_mods20151021.xlsx".*
- *Many other WMO, ESA, ECMWF, NRC references*

Rank Order of Objectives 1-10 in Group A

Rank Order (priority for improvement) and swing weight	Objective	ST level comments	Rationale for ranking
1 0.1268957	3-D winds	Some capability from atmospheric motion vectors from ABI. Large room for improvement	Holy Grail of NWP, and not well provided now. Very important to provide above ST level of NONE. Top priority for improvement.
2 0.1232025	RT regional wx imagery	ST level significantly below current capability	Other objectives provided in part by foreign partners; this one must be provided by the US. Important for severe wx warnings, incl. hurricanes, tornadoes. High priority for improvement.
3 0.117956	Global GNSS RO soundings	Relatively low level of capability (5,000 global soundings per day) far below optimum.	Major contributor to NWP, improves performance of IR. MW sounders, space weather and climate applications. High priority for improvement.
4 0.1107445	Global RT imagery	Important, significant capability at ST level with GOES-R series, EUMETSAT, and Japan satellites	Tropical cyclones, global cloud cover, extra-tropical storms. Important to US, but not as important as GOES. Significant capability at ST lowers its priority for improvement.
5 0.101262	Global RT MW soundings	Significant capability at ST level.	One of top contributors to NWP. Large capability at current and ST levels, which lowers its priority for improvement.
6 0.0895125	Global RT IR soundings	High level of ST, but not as high as current capability	One of top contributors to NWP. High capability at current and ST levels reduces its priority for improvement.
7 0.0759965	Global sfc vector winds	Significant with SCA scatterometer (EUMETSAT)	Important for NWP, ocean applications. Significant ST level -> medium priority for improvement.
8 0.0617462	Non-RT global wx imagery	6 bands is below current capability	Supports large number of applications and users. Significant ST level -> medium/high priority for improvement.
9 0.0480788	Global ocean color/phytoplankton composition	VIIRS is ST level	Supports variety of ocean applications. Significant ST level -> medium priority for improvement.
10 0.0361549	Microwave imagery	Fairly high ST level, but currently declining due to loss of SSMIS	Medium ranking due to existing/planned sensors (JPSS, GPM), but strong contribution to passive precip rates and tropical cyclone analysis.

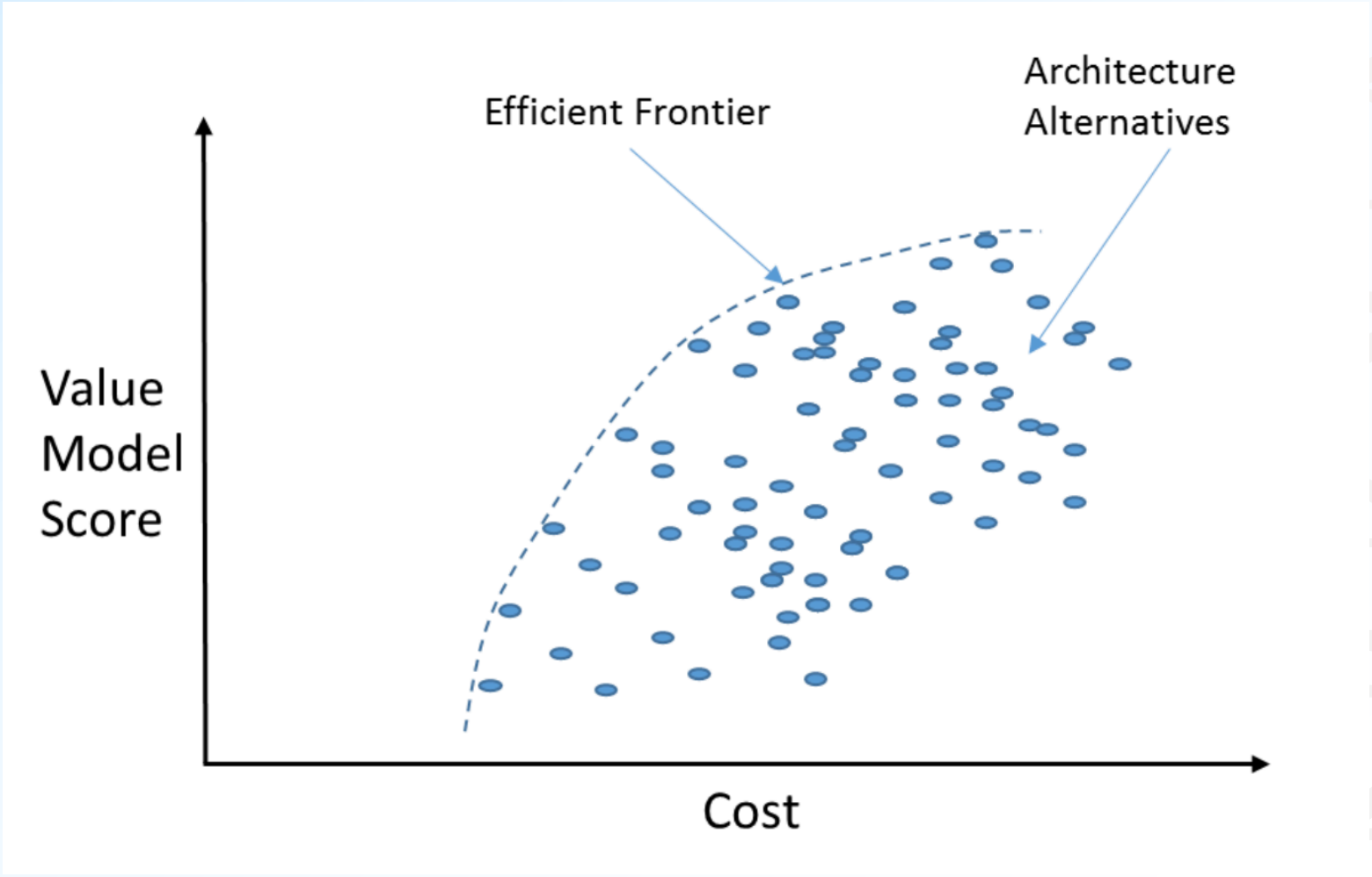
Rank order of Objectives 11-19 in Group A

11 0.0266211	Lightning	None (significantly below current capability of GLM on GOES-R)	Moderate importance for NOAA situational awareness operations, nothing at ST level -> medium level priority for improvement.
12 0.0195448	Radar-based global precipitation rates	None at ST level. Current capability includes DPR in GPM. Significant IR and MW assets also exist.	Low/medium priority for NOAA ops and significant ST level from other Objectives -> low priority for improvement.
13 0.0145955	Regional MW soundings	None, except significant contribution from global system.	Improvements in global system also improve regional, so priority for improvement relatively low.
14 0.0112857	Regional IR soundings	None, except some contribution from global system and ABI on GOES-16.	Improvements in global system also improve regional system, so priority for improvement relatively low.
15 0.0091432	Global sea sfc height	Significant capability (JASON-3) (Also JASON-2) – ST high	Important climate change indicator, global ocean models. Significant ST level implies low priority for improvement.
16 0.0077877	Global chemical conc	None	Fairly low priority for NOAA operations, but NONE at ST level -> increases priority for improvement.
17 0.0069435	Ozone	Significant-OMPS, IASI-current level	Low/medium priority for NOAA ops and significant ST level-> low priority for improvement.
18 0.0064232	Outgoing LW Radiation	Significant capability at ST level	Relatively low priority for NOAA ops, significant ST level --> low priority for improvement.
19 0.0061049	Incoming solar radiation	Significant capability at ST level	Relatively low priority for NOAA ops, significant ST level -> low priority for improvement.

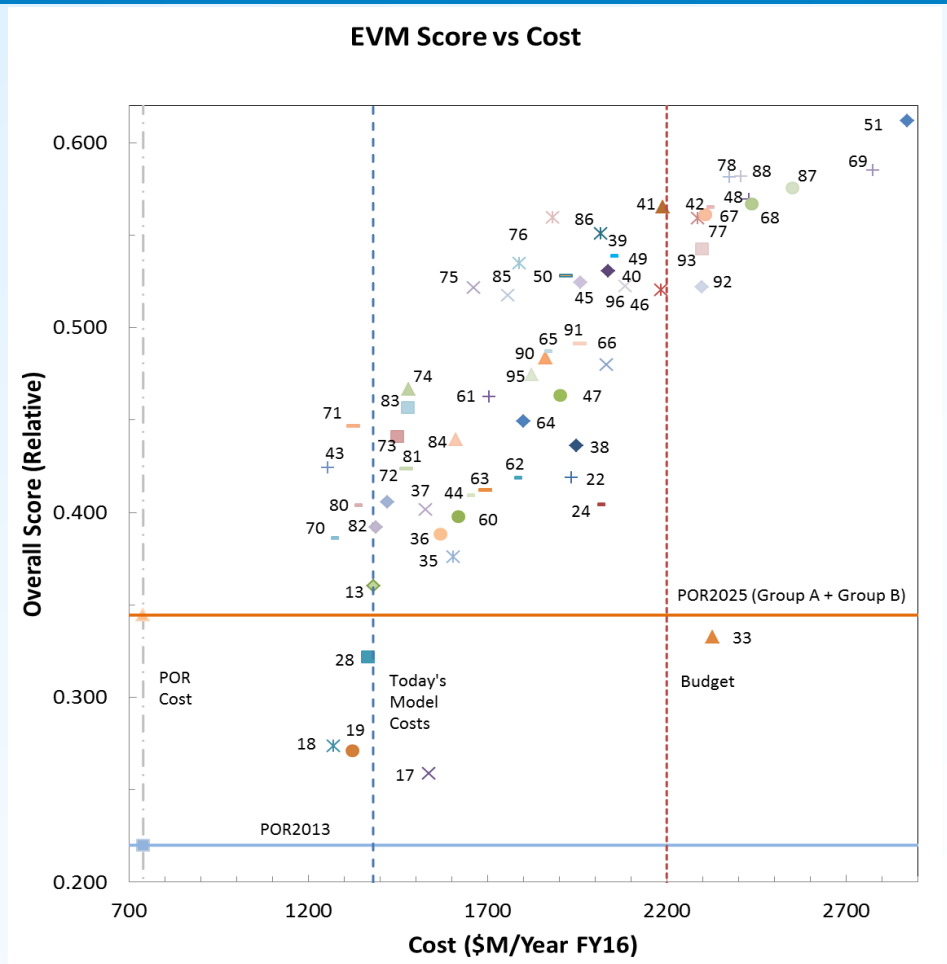
Use of EVM

- *Each objective scored for any proposed constellation based on weighted scores of each performance attribute of that objective*
- *Cost of each constellation estimated*
- *Overall score of each constellation plotted against cost in "efficient frontier" diagram*

Efficient Frontier Chart-Schematic



Example of an actual Efficient Frontier Diagram



Source: Mark Maier, NSOSA

SPRWG Final Report (May 2017)

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Assessment of the SPRWG Process

Positives

- *Process was objective and thorough and worked well*
- *Iteration through 3 cycles very important*
- *SPRWG independence respected by NOAA*
- *SPRWG members cooperated and argued respectfully and constructively*
- *The EVM process of ranking improvements over existing capability was new to all SPRWG members-took some getting used to.*
- *Working with Mark Maier and NESDIS leadership was a pleasure*

What could be improved

- *Peer review of SPRWG draft report*
- *Nature of process required detailed-oriented subject-matter experts. Membership was a bit uneven in this regard.*
- *Space Weather was underrepresented-mitigated by involving outside experts as needed.*

Acknowledgments

- ***Monica Coakley (MIT Lincoln Labs)-worked closely with SPRWG in scoring the EVM objectives***
- ***Steve Volz, Karen St. Germain, Frank Gallagher (NOAA/NESDIS)-overall leadership and support of this study***